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IMPLICATIONS FOR ARMS CONTROL IN TECHNOLOGY TRANSFER TO LESS DEVELOPED COUNTRIES (LDC'S)

Essays on the Role of Coproduction and
Dual-Use Technology
in the
Development of LDC Arms Industries

AC8WC122

Volume IV

Prepared For

U.S. ARMS CONTROL & DISARMAMENT AGENCY

Prepared By

Science Applications, Inc.
Center for Security & Policy Studies
1710 Goodridge Drive
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This volume examines motivating factors, infrastructures, and patterns in arms development and production, as they relate to the role of coproduction and dual-use technologies in the development of indigenous arms industries in LDC's.

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SUMMARY:

This is one of a series of four volumes of technical reports which address the implications for arms control in technology transfer to less developed countries. The four volumes include:

Volume I - Considerations in Controlling Dual-Use Technology Products: An Overview (Unclassified)

Volume II - Exploitation of Civil Inertial Navigation Systems (INS) for Military Purposes by Less Developed Countries (LDC'S) (Confidential)

Volume III - A Study of the Exploitation of Dual-Use Technologies: South Korea (Confidential)

Volume IV* ** - Essays on the Role of Coproduction and Dual-Use Technology in the Development of LDC Arms Industries (Unclassified)

This volume examines motivating factors, infrastructures, and patterns in arms development and production, as they relate to the role of coproduction and dual-use technologies in the development of indigenous arms industries in LDC's.

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* This volume.
** Includes index to all four volumes.

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INTRODUCTION

This examination of the role of coproduction and dual-use technology (DUT) in the development of arms industries in less developed countries (LDCs) will first survey the factors motivating LDCs to produce armaments locally and then consider the scientific, technical and industrial infrastructure required for such production. There are distinctive patterns in the manner whereby LDCs progress toward indigenous arms production and these will be described. There are a number of military technologies and DUTs which will, as their application expands, affect future LDC arms production. These will be identified with particular reference to their application to those weapons systems with potentially greater destabilizing impact such as surface-to-surface guided missiles, as well as their effect on coproduction and licensing agreements in which virtually all LDCs—and most developed countries—participate at some stage in the production of complex products, including modern arms. Because current trends in the design, production and application of modular components can significantly upgrade and greatly extend the effective life of sophisticated weapons systems, current trends in this area will also be examined.

The data contained in this volume are based in large part on studies of weapons acquisition and production patterns in ten LDCs reviewed as part of the overall interagency study of the Executive Branch.* Information on other LDCs is introduced as available and pertinent. With regard to the LDCs subjected to special study, a caution is suggested. There are several reasons for questioning the applicability of the Israeli model to other LDCs. While numerous similarities do exist, particularly since Israel has followed the general pattern of other LDCs in the acquisition of arms and development of an indigenous arms industry, there are important differences which could argue against drawing too heavily on the Israeli experience as a guide to future developments in other LDCs:

- In terms of population, (3.6 million, including Arabs) Israel compares very unfavorably with the other nine whose population ranges from 246 million for

* Ten countries studied are listed in Table 1, page 7.

India, 110 million for Brazil, 40 million for South Korea, etc. In addition, since 1973 a significant "brain drain" has developed.

- Although Israel's per capita GNP ($3,720) is higher than any of the LDCs studied, its overall GNP is only $13 billion ranking it next to last in the group (North Korea—$10 billion).

- Israel has almost no natural and energy resources. Despite this, Israel does have a degree of managerial and technical expertise unmatched by any of the other LDC's studied.

- The magnitude and immediacy of the threat to Israel's national existence in terms of the size and military capabilities of potential enemies is greater than that of any of the countries studied.

- Because of this and as a result of the unique circumstances which led to its founding as a nation, Israel has enjoyed special access to foreign technology not only in the United States but in Western Europe as well.

- Unlike many of the other regional conflicts which have taken place or are threatened in some areas, those involving Israel and its neighbors since 1956 have been virtually superpower confrontations by proxy involving "state-of-the-art" weapons systems on both sides.

- The peculiar nature of Israel's confrontations with its neighbors has meant that Israel will (a) incur defense expenditures which it can never hope realistically to offset through export of weapons indigenously manufactured regardless of their quality, and (b) continue to acquire advanced systems from foreign suppliers.

It is our view, therefore, that although Israel's actions to achieve indigenous arms production capabilities provide useful indicators on how LDC's so strive, it cannot serve as a complete model because of the uniqueness of its origin, its position in the world geopolitical, environment, and its relatively high order of sophisticated technological skills and knowledge.

DEFINITIONS OF KEY TERMS

The definitions set forth below are working definitions and are not meant to be exhaustive. There are numerous variations, particularly with regard to licensing arrangements, and there are no sharp distinctions made in much of the literature on LDC arms production between "licensed production" and "indigenous production." Additional detail on this aspect of the problem can be found in the later section on "Patterns of LDC Arms Development and Production."

Dual-Use Technology:

As used in this annex, dual-use technology (DUT) may be defined as that technology which is applicable to both civilian and military requirements. Military application may be either direct and specific (utilization of a microprocessor in the target acquisition and fire control system of modern surface-to-air missiles) or indirect and general (construction of an integrated steel mill as a prerequisite to production of modern artillery). Export of DUTs is normally controlled by the Department of Commerce through the Commodity Control List rather than the Department of State through the International Traffic in Arms Regulations (ITAR).

Licensed Production:

Production authorized by the firm or firms which developed the weapons system or sub-system (owner). Licensed production can take these forms:

- Assembly: The assembly of all or part of the system using components provided by the owner.

- Partial Production: The owner licenses a foreign firm to produce the system in its own facilities but continues to provide many of the components. This is often done because the owner desires to protect proprietary technology or retain a commercial advantage. Also, the licensee may feel that this is a more economical approach even though it is capable of producing the components in question. Because the percentage of locally produced components of a given system may be very high, and because the licensee provides much or all of the capital, labor force, raw materials, etc., partial production under license is often referred to as "indigenous production."

- Coproduction: Production of part or all of the systems produced in conjunction with other producers including the owner in which the coproducer supplies part of his production to other members of his group for use in manufacturing the final product. Coproduction can be limited (and often is) to bilateral agreements between an LDC and owner or can refer to the more complex, production consortia arrangements such as those in effect among certain NATO countries for coproduction of the U.S. F-16 aircraft.

Indigenous Production:

Design and manufacture of a weapons system locally. In such cases, albeit rare for advanced weapons systems, input to the development and production process is primarily indigenous.

SURVEY OF FACTORS MOTIVATING LDC ARMS INDUSTRIES

Among LDCs studied, motivations for developing a capability to produce arms are as diverse as the countries themselves. It is difficult to discern firm patterns even when the countries are grouped according to region or tier. Several rationales, ranging from perceived threats of attack to the need for foreign exchange, were examined. None of them applied in precisely the same degree to each of the countries concerned. We did, however, establish that if a common factor exists, it is the desire of these LDCs to free themselves from foreign domination of the arms trade. Each of them has had experiences in which traditional arms suppliers have taken action which an individual country, rightly or wrongly, considered inimical to its national interest. These tendencies to seek independence in arms production are in harmony with the growing sense of frustration felt by developing nations because of their continuing economic dependence on the developed world. It is unlikely, therefore, that we shall see any diminution of efforts by LDCs to create local armaments industries. Understandably, progress toward this goal has not been uniform among the ten countries reviewed but there appears to be general agreement on the concept.

Table 1, showing the scope of arms production activities of these LDCs, indicates that with few exceptions, their high motivation to develop arms industries has resulted in their producing a wide range of systems. At the same time, the mix of motives in some cases influenced the rate in which policy has been implemented. Table 2 sets forth the factors we believe important in motivating decisions on indigenous arms production. They are discussed below.

SECURITY FACTORS

Threat of attack by a hostile neighbor or coalition of neighbors ranks high as a determining factor in seven of the ten countries. In each case the threat derives from traditional rivalries some of which have resulted in armed conflict on at least one occasion:

- Egypt — Israel
- India — (Pakistan, PRC)
- South Korea — North Korea
- Taiwan — (PRC)
- Yugoslavia — (USSR, Warsaw Pact neighbors)

TABLE 1. SCOPE OF ARMS PRODUCTION ACTIVITIES

	MILITARY AIRCRAFT	MISSILES	AFV's*	WARSHIPS
ARGENTINA	✓	✓	✓	✓
BRAZIL	✓	✓	✓	✓
EGYPT		✓	✓	
INDIA	✓	✓	✓	✓
ISRAEL	✓	✓	✓	✓
KOREA, NORTH		✓	✓	✓
KOREA, SOUTH		✓	✓	✓
SOUTH AFRICA	✓	✓	✓	✓
TAIWAN	✓	✓		✓
YUGOSLAVIA	✓	✓	✓	✓

* Armored Fighting Vehicles, i.e., tanks armored cars and armored personnel carriers.

TABLE 2. MOTIVATIONAL FACTORS

FACTORS \ COUNTRIES	ARGENTINA	BRAZIL	EGYPT	INDIA	ISRAEL	KOREA, NORTH	KOREA, SOUTH	SOUTH AFRICA	TAIWAN	YUGOSLAVIA
SECURITY FACTORS*										
Perceived threat of attack	2	1	4	4	5	4	5	3	5	4
Domestic unrest, armed insurrection	4	3	1	1	2	1	3	5	2	2
POLITICAL FACTORS										
Perception of regional or global role	4	5	4	4	5	3	3	4	4	5
Military/authoritarian regime	5	5	5	1	2	5	5	5	5	5
International or regional isolation	2	1	3	2	4	2	2	5	5	2
Unwillingness to accept constraints on arms utilization imposed by foreign suppliers	3	3	4	4	5	4	4	5	5	4
Concern over possible weapons/spare parts arising from domestic policies or adversary pressures on suppliers.	5	4	3	5	5	5	5	5	5	4
ECONOMIC FACTORS										
Balance of trade	4	5	3	1	4	3	3	1	2	4
Economic growth	4	4	4	2	2	3	3	3	2	3
Expansion of employment base	4	4	5	3	3	3	3	1	3	4

* Weighting Scale—low to high 1-5.

The reality of these concerns is also reflected in other indicators. For example, of the six of the countries on our list facing traditional enemies, five ranked highest in 1976 in terms of percentage of GNP devoted to military expenditures and members of the armed forces per 1000 of population.[1]

Percentage of GNP	
Israel	32.2
Egypt	10.5
North Korea	9.6
Taiwan	8.9
South Korea	6.1
South Africa	5.4
Yugoslavia	5.0*
India	3.4
Argentina	2.4
Brazil	1.3

Armed Forces Members Per 1000 of Population	
Israel	52.63
North Korea	29.41
Taiwan	28.37
South Korea	16.53
Yugoslavia	12.79
Egypt	10.53
Argentina	5.9
Brazil	4.09
India	2.23
South Africa	2.20**

[1] World Military Expenditures and Arms Transfers 1967-1976, U.S. Arms Control and Disarmament Agency, July 1978. All figures based on 1975 constant dollars. Data for Taiwan are for 1975. The 1976 figures not available.

* 1976 figures for Yugoslavia not available; figure is for 1975.

** Note: This figure is based on total population. However, since the armed forces are composed predominantly of whites, who make up approximately 18 percent of the population, the ratio of armed forces per 1000 of the white population would be much higher. (∿12.2).

Despite the correlation between defense outlays, military manpower commitments and concern over possible attack, the latter is not always the most accurate indicator of the growth of indigenous arms production. For example, Brazil is not troubled by fears of invasion but has made great strides in arms production. Prior to 1973, Brazil was not an arms exporter but by 1976 it ranked second to Israel, the leading exporter of irdigenously produced arms in the developing world. This suggests we will need to look elsewhere for Brazil's motivation. In addition, external threat motivation may change over time as perceptions of the immediacy of the threat evolve and other factors become more important to arms production. In Yugoslavia's case, concern over possible Soviet or Warsaw Pact military intervention clearly provided the initial motivation for developing an indigenous arms production capability; but in recent years exports to the Third World have become a paramount consideration both to improve Yugoslavia's chronic balance of payments problems and to enhance the country's position as a leader of the Non-Aligned Movement.

Apart from the threat of attack, there are other security considerations which predispose some of the countries on the list to foster indigenous arms production. These factors relate to concerns over domestic unrest sparked by political opponents or ethnic rivalries. Such unrest, particularly if provided external assistance, can develop into armed insurrection. Opposition elements exist to some degree in nearly all of the countries studied, but only one, South Africa, faces problems of a degree that must have influenced its indigenous arms production policies. Because current and potential unrest in South Africa derives from its racial policies, the country faces growing isolation. As a so-called "pariah" state it has faced constraints in arms procurement and this factor, discussed below, has served to reinforce South Africa's determination to insure that it possess the weapons it will need to "maintain internal security," and have a free hand to cope with externally supported rebellion and even invasion should this develop.

POLITICAL FACTORS

Political influences affecting decisions to develop indigenous arms production are more subtle and less susceptible to precise defination than either security factors or economic considerations. Nevertheless, they play a vital role in determining the scope and pace of arms production programs, even when other factors, such as threat of attack or balance of payments problems supply the initial impetus for the policy decision. For this discussion, political factors have been grouped under three major headings: The National Self-image, The Nature of the Regime, and Supplier-Recipient Relationships.

National Self-Image

The perception held by a nation's elites of its global or regional role will frequently provide important clues to decision-making on defense related matters. The energy crises which began in 1973 created balance of payments problems for Brazil and all other LDCs. In Brazil's case, growing arms exports have helped somewhat to alleviate those problems. Nevertheless, had Brazil not had a self-image whereby Brazilians saw themselves as the leading South American power, it is doubtful if the arms industry would have received the attention it did. Conversely, it is Argentina's conviction that it occupies a special place among Spanish-speaking countries of Latin America. It is this conviction rather than fear of actual invasion by its neighbors which has contributed, along with other factors, to its decision to create its own armaments industry. As suggested above, prestige considerations related to Yugoslavia's sense of its role in the Non-Aligned Movement have reinforced Yugoslavia's determination to support an indigenous arms industry.

While none of the LDCs studied actually aspires to world power status, certain of them such as Brazil and India have come to expect the world community to accept them as the dominant power in their respective regions. Egypt enjoyed this status among the Arab states, but the peace arrangements with Israel have brought about challenges to Egypt's position which adversely affected Egyptian plans to expand its arms production capability. The dissolution of the Arab Organization for Industrialization (AOI) earlier in 1979 brought about major changes and some cancellation to many projects. It is too soon to predict how new Egyptian arrangements for assistance from the U.S. will work out and how evolution of the "peace process" will affect Egypt's long-term relations with the Arab world.

The Nature of the Regime

The nature of individual LDC regimes will also impact on arms production policies, but normally in concert with other factors, most of which can be traced to the political system and ideology in effect in a given country. Aside from India and Israel, none of the LDCs reviewed adhere to democratic norms although the kind and degree of actual political repression vary considerably from country to country. Two, North Korea and Yugoslavia, are Communist states (albeit greatly dissimilar). Many LDCs studied are regimes in which active-duty or former military officers occupy key governmental positions and the influence of the armed forces is strong. Because state leaders rely heavily on the armed forces in their administration of government, there is a tendency to go along with the desires of the military for improved weapons systems. At the same time, military-dominated regimes are particularly sensitive to internal opposition and the desire to suppress such opposition adds to the pressures for enhanced arms production capabilities. Argentina and Brazil, in Latin America, are excellent examples of this tendency. Similar influences are at work in South Korea and Taiwan where they reinforce the motivation for arms production already present because of fear of hostile attack. For one reason or another, then, such countries have motivations leading to large standing armed forces which of themselves create a market demand for military goods which can stimulate indigenous arms production programs.

In some cases, the nature of its regime can result in isolation of a country by the world community or within its own region. South Africa, within the group reviewed, is the best example of a "pariah" regime whose isolation is due to its racial policies. This sense of isolation together with the U.N. arms embargo directed at South Africa since November 1977 have made it imperative that it create an indigenous arms production capability, at least for those weapons systems it considers essential to the maintenance of internal security and an adequate defense against its African neighbors.

For example, the South Africans designed, developed, and are now producing the "Ratel (Badger)," a wheeled, armored vehicle to meet both internal security operational needs and other defense requirements of the South African Army. The "Ratel" closely resembles the French Berliet VXB and its design probably reflects the special relationship South Africa has enjoyed over time with France. Some aspects of this relationship may well survive the embargo. For example, the French AML-90 armored car, the 90 mm gun turret of which is being adapted for one version of the "Ratel," still is produced under license in South Africa. Nonetheless, South Africa doubtless recognizes that the very survival of the present regime will depend on its ability to produce selected weapons systems containing a high percentage of locally manufactured components.

There are, of course, cases in which a nation may be isolated for reasons other than the nature of its political system. Israel was isolated by Arab neighbors for many years and Taiwan is becoming increasingly isolated because of pressures on its friends and trading partners by the Peoples Republic of China. In these cases, however, it was not the regional isolation but other factors arising from supplier-recipient relationships which gave impetus to the development of arms production capabilities. In the case of Taiwan, the PRC factor has placed stringent limitations on the kinds of weapons systems it can obtain from the U.S., its traditional supplier. More significantly, it has very nearly eliminated West European alternatives because of the reluctance of the countries concerned to risk irritating the PRC. The result is to isolate Taiwan almost completely, thus denying it access to the high technology weapons systems it believes it must have to preserve its independence.

Supplier-Recipient Relationships

Nothing has served to stimulate the development of domestic arms production more than the reliance of LDCs on superpower arms suppliers and the tendency of the latter to dictate the terms whereby LDCs can employ the arms they purchase, or manufacture under license. Worse, from an LDC point of view, has been the readiness of arms suppliers to interrupt shipments of weapons systems and spare parts at times when the very existence of a given LDC was threatened. Here are a few examples taken from the experiences of the ten countries studied of the "father knows best" attitude which has characterized relations between supplier nations and the developing world:

Argentina: 1977	U.S. determines that no credit or cash military sales can be made to Argentina because of its denial of human rights.
Brazil: 1977	Brazil included in list of countries to whom no credit can be extended by the U.S. for military purchases. Refusal of U.S. to approve sale or coproduction of certain high performance combat aircraft, missile guidance systems, etc.
Egypt: 1973	USSR curtailment of supplier relationships with Egypt, denial of spare parts and pressures on other clients such as North Korea to do the same.
India: 1971	U.S. "tilt" toward Pakistan and arms embargo (and since) during the 1971 India-Pakistan war.
1974	Soviet refusal to permit India to furnish Egypt with parts from MIG-21s produced under Soviet license in India.
Israel: 1967	France, hitherto the major foreign supplier, declared a total arms embargo.
1973	The United Kingdom refused to deliver spare parts for Centurion tanks.
1978-79	Because it contained U.S. components, the U.S. blocked the sale of the Israeli "Kfir" fighter to Ecuador.
Korea, North: 1970s	USSR refusal since 1974 to supply North Korea with advanced aircraft.

Korea, South:	1971-77	Curtailment in levels of U.S. military assistance; U.S. plans to continue reductions in its forces in Korea.
Taiwan:	1978	U.S. refusal to sell advanced combat aircraft (F-16); U.S. recognition of PRC. Kfir turndown (see above).

These actions by suppliers clearly accelerated trends to indigenous arms production by many LDCs, more and more of whom proclaimed their determination to achieve independence in weapons acquisition. If their "independence" is to be judged by the percentage of imported components contained in the weapons they produce, then none of the LDCs have reached their goal. In manufacturing modern military aircraft, missiles, armored vehicles or naval vessels, they all require some degree of foreign assistance which normally takes the form of direct import of key components in their production locally under license. Despite this, many LDCs have indeed achieved greater independence in arms acquisition, particularly in cases which involved a shift from a traditional, sole supplier relationship, to the exercise of the multiple options which are now available as manufacturers in Western Europe and several Communist countries become more competitive technologically and more liberal in their willingness to meet LDC needs.

ECONOMIC FACTORS

Economic considerations are evident in the indigenous arms production policies of each of the countries studied but with few exceptions they were not the source of the initial motivation. In every case, the impetus for creating or expanding an indigenous arms industry derived from one or more of the factors described above relating to national security and independence. Nonetheless, economic factors have emerged in some LDCs as important elements in decisions to "make or buy" weapons systems. These factors included the need to counter an unfavorable trade balance, stimulation of industrial growth, reduction of massive unemployment, slowing of the "brain drain," etc.

Balance of Payments

The extent to which these deficits in their balances receive emphasis in motivating the development of indigenous arms production varies greatly with each LDC. For example, while many of the LDCs studied export some portion of the arms produced locally and overall LDC exports of arms are increasing, in most cases they have not contributed significantly to reducing the balance of payments. For Brazil, arms exports have come to be a determining factor in arms production even though the needs of its own forces remain an important consideration. This derives from the impact on the Brazilian trade balance caused by increased energy costs but also from the success enjoyed by Brazil in marketing conventional arms such as their wheeled armored vehicles to oil producing states (Iraq, Libya). In 1974, Brazil had no arms exports, yet by 1976 it covered one-half of the cost of its arms imports ($82 million in exports versus $161 million imported).

Exports have also assumed considerable importance to the Yugoslav arms industry. The motivation for exporting large portions of its current production of ground forces materiel to other LDCs may largely relate to Yugoslavia's role in the Non-Aligned Movement, but at the same time this practice has contributed to the country's trade balance. In 1976, Yugoslav arms imports amounted to $82 million yet exports equaled $98 million. In 1978, arms deliveries totaled $59 million, but exports reached $130 million.

Israel, on the other hand, which still leads LDCs in arms exports and conducts extensive arms marketing activities, has covered only a fraction of its arms imports. In 1978, it earned $470 million from arms sales but it spent $2.5 billion for defense in foreign exchange. It is unlikely that this trend will be reversed. In fact, as the political climate for Israeli exports changes, other LDCs such as Brazil might take over Israel's lead.

In sum, LDC arms exports will continue to grow and will consist primarily of low to intermediate technology items. However, their principal customers will be other LDCs except in the case of OPEC nations. The latter usually demand and can generally obtain advanced systems which are obtainable only from the leading industrial nations (Brazilian sales of armored vehicles to Libya and Iraq are an exception). Nevertheless, there seems little prospect that LDC arms exports can reduce overall trade deficits in any significant way. In fact, it is not uncommon for LDC's to embark on weapons systems coproduction projects only to find that the costs to them in foreign exchange were unacceptable. This phenomenon is not, however, restricted to arms production sectors of a LDC economy.

Growth of the Industrial Infrastructure

While in several LDCs the growth of the arms industry was seen as an element of the general pattern of economic growth, in none (with the possible exception of Egypt) was this a major, motivating factor. In Brazil, the arms industry is only one element of the National Development Plan which guides Brazilian efforts to expand the overall economy. South Korea had already developed a thriving economy with extensive international trade connections when in the early 1970s it began to graft an arms production capability on existing industrial establishments. This action was taken, as we pointed out above, in response to perceived changes in the supplier-recipient relationship The Taiwanese experience was similar. Egypt, on the other hand, sought Arab investment in an Egyptian-based arms industry because its development would lead to the creation of an industrial infrastructure which would provide spinoffs to the civilian sector. It isn't clear, however, that such spinoffs would do more than enhance a few sectors of a LDC, such as the heavy industries. Concentration of capital in armament industries might, in fact, inhibit the growth of other key sectors of a LDC's economy, dependent upon its overall economic situation.

Reduction of Unemployment/Slowing "Brain Drain"

Another reflection of economic concern which has impacted on decisions to expand indigenous arms production by some countries relates to their need to expand employment opportunities. For some, such as Egypt, any industrial development, including the manufacture of armaments, promises to assist in the reduction of chronic unemployment and to create new skills. For others, such as Brazil and India (but not confined to them), the development of an indigenous arms industry is another element in limiting or even reversing the "brain drain," the flow of skilled engineers and other technically trained personnel to the developed countries where their opportunities, both professional and financial, are greater than at home. Thus, those countries capable of producing qualified cadres see in the design and production of advanced weapons systems another factor which acts to retain such cadres despite the lures of the industrialized world. It is significant that even Israel continues to experience shortages in skilled personnel needed in some sectors of its armaments industry.

SCIENTIFIC, TECHNICAL AND INDUSTRIAL INFRASTRUCTURE REQUIRED FOR TECHNOLOGY ABSORPTION AND INDIGENOUS ARMS PRODUCTION

In considering the application of dual-use technologies to weapons manufacture by the LDCs under study, we recognized that the facility with which such technologies can be applied to the manufacture of weapons systems depends on the technical-economic base possessed by individual LDCs and their ability to absorb the wide range of technologies found in modern industry. Table 3 illustrates the kinds of dual-use technologies which would be essential to more advanced weapons construction. Even less sophisticated weapons, however, including the ground force ordnance items which constitute the principal export lines of many of the LDCs studied, depend on a broad range of dual-use technologies, particularly those related to metal processing. How well LDCs can cope with the many technologies involved is a function of the level of development of their scientific, technical and industrial infrastructure. The latter is in turn a product of historical forces, the political framework whereby the economy is directed, the financial structure, the availability of managerial and technical skills, and natural resources. As indicated earlier, the majority of the LDCs studied are governed by the authoritarian regimes. Israel and India are the exceptions yet even in their case they share the predilection of the others for centrally directed, planned economies and government ownership of key industries. Such central direction may or may not be an efficient mechanism for coping with the totality of economic concerns confronting LDCs, but it does provide a framework for implementing national policy with respect to investment in industrial development and resource allocation to military requirements. For example, even though India inherited a rather well-developed infrastructure from the British at independence, during the period 1950-1970 it invested more than 80 billion rupees in improving this infrastructure, especially in the power, communication and transportation sectors. Following the Indo-Pakistani War of 1971, investment in military-related facilities increased and India built one of the Third World's most impressive military-industrial complexes.

On a more sophisticated level, Brazil has encouraged the development of its industrial infrastructure through its successive plans for "National Development" and the creation of the bureaucratic machinery necessary to insure their implementation. Brazil's arms industry is but one segment of a larger, coordinated, national effort to

TABLE 3

SELECTED KEY DUAL-USE TECHNOLOGIES
FOR
INDIGENOUS WEAPON SYSTEM CAPABILITY

WEAPON SYSTEMS / TECHNOLOGIES	COMPUTER-CONTROLLED METALWORKING	TURBINE ENGINE MANUFACTURING	MOS/LSI MANUFACTURING	MICROWAVE SOLID STATE DEVICES	MEDIUM POWER LASERS	IR DETECTORS & MATERIAL	ARRAY PROCESSORS	COMPOSITE MATERIALS
AIRCRAFT	• CONTOURED SKIN MILLING	• TURBINE BLADE FABRICATION	• VAPOR DEPOSITION	• FIRE CONTROL SYSTEMS DESIGN/MFG.	• TARGET ACQUISITION SENSOR DESIGN/MFG.	• TARGET ACQUISITION SENSORS DESIGN/MFG.	• SLAR DESIGN MANUFACTURE	• AIRCRAFT STRUCTURE DESIGN/MFG.
MISSILES IRBM/ICBM	• FILAMENT WINDING	• TURBOPUMP DESIGN/MFG	• GUIDANCE CONTROL & NAVIGATION SYSTEMS MFG.	• COMMAND/CONTROL SYSTEMS	• GUIDANCE SYSTEMS	• OPTICAL TRACKING	• FOCAL PLANE ARRAYS	• ROCKET NOZZLE FABRICATION
CRUISE	• CONTOURED STRUCTURE MILLING	• SMALL ENGINE DESIGN/MFR.		• TERRAIN AVOIDANCE SENSORS	• TERMINAL HOMING SYSTEMS	• TERMINAL HOMING SYSTEMS		• MISSILE STRUCTURE DESIGN/MFR.
CHEMICAL WARFARE	• SUBMUNITION & BOMBLET DESIGN/MFR.			• RADAR FUZE DESIGN/MFR.				• BINARY SYSTEMS
ARMORED VEHICLES	• MULTI-AXIS MACHINING	• POWER TRAIN FABRICATION	• TACTICAL COMMUNICATIONS	• FIRE CONTROL SYSTEMS DESIGN/MFG.	• TARGET ACQUISITION SENSORS DESIGN/MFG.	• TARGET ACQUISITION SENSORS DESIGN/MFG		• TANK STRUCTURE DESIGN/MFG
SHIPS	• AUTOMATIC WELDING	• MARINE ENGINE FABRICATION	• TACTICAL COMMUNICATIONS MFG.	• FIRE CONTROL SYSTEMS	• TARGET ACQUISITION & TRACKING	• TARGET ACQUISITION & TRACKING	• ACOUSTIC ASW PROCESSORS	• SHIP ARCHITECTURE
EW			• HIGH-DATA-RATE SIGNAL PROCESSES	• JAM/ANTIJAM CIRCUITS & DEVICES	• OPTICAL COMMUNICATIONS DESIGN/MFG.	• CCD/FET DEVICE DESIGN/MFG.	• SIGINT	
C^3			• LARGE-SCALE DATA HANDLING SYSTEMS	• RADAR SURVEILLANCE SYSTEMS	• BLUE GREEN UNDERWATER COMMUNICATIONS SYSTEMS	• SURVEILLANCE AND MAPPING SYSTEMS	• MULTI-SENSOR INTEGRATION	• SATELLITE PLATFORM DESIGN/MFG.

achieve technological independence. This effort, which relies heavily on technology transfer via coproduction agreements, has resulted in continually expanding and upgrading the quality of Brazil's industrial base.

On a smaller scale, but equally impressive as an example of the advantages of centrally directed institutions in the development of an indigenous arms production capability, is the South Korean experience. In this case the decision was made to exploit appropriate segments of a rapidly growing civilian industrial base for the production of a variety of weapons systems and military material. Existing civilian industries were selected to produce defense-related items although an effort was made to limit arms production to a fixed percentage of total output. Plans for development of the arms industry, decisions on research and development, and on levels of investment were concentrated in a single entity, the Agency for Defense Development (ADD).

Human resources in the form of managerial, scientific and technical skills are vital to the development of an indigenous arms production capability. There are correlations between such factors as percentage of GNP spent on education, literacy rates, size of scientific and technical cadres, numbers of students in scientific education programs, number of technical publications, etc., and levels reached by a given country in its progress toward achieving an in-country arms production capability. As in the case of industrial development, however, these statistics are subject to misinterpretation with regard to some countries. For example, Pakistan has a literacy rate which falls below 30 percent yet it ranks not unfavorably with some of the LDCs studied in the number of scientific students (10,000 or more) or the sum of its scientific, engineering and technical cadres (100,000 or more). At the same time, Pakistan ranks low in terms of percentage of GNP spent on education generally. Egypt also follows this pattern with a literacy rate of 40 percent while claiming a total of over 500,000 scientists and engineers. India offers an even more extreme example with a literacy rate of 29 percent and approximately 1,175,000 scientists and engineers. These countries reflect extreme examples of a practice common to most LDCs whereby selected elites are provided increasingly higher levels of the scientific-technical training necessary to an industrialized society as a result of government policy. This explains in part their ability to sustain expanding arms production despite low literacy rates. On balance, therefore, there is every indication that the governments concerned will seek to maintain sufficient levels of scientific and technical education to insure that the needs of the armaments industry are taken into consideration. This does not mean that the available scientific and technical cadres can actually meet the requirements of increasingly complex weapons development. Shortages, particularly of individuals with managerial experience, face each of the LDCs studied in varying degrees and will prove a major factor in inhibiting the ability of these countries to produce high technology systems. On the other hand, the number of key individuals required is not great and in some cases LDC shortcomings in this area have been made up by utilizing foreign exports under contract.

Financial resources and the ability of LDCs to allocate them without political constraints will be important in determining the rate of growth of an indigenous armaments industry and the size of the military forces generally. All of our LDCs rank high in the Third World in terms of GNP, even though they are not petroleum producers. With a 1977 GNP of $163 billion, Brazil dominates the group, but even North Korea, which has the lowest GNP, managed a total in excess of $10 billion in 1976. It is, however, less a question of total wealth than allocation and in this regard, most of the countries studied have internal financial institutions which regulate investment in terms of the national economic policy promulgated by the central institutions described above. In India this is the Industrial Development Bank which directs the marketing, investment, research and technical development in the country. Similar institutions for channeling investments exist elsewhere in the group of 10 LDCs. As a result, government policy to develop an independent capability to produce arms can be implemented through investment programs which maintain the desired level of growth even as the GNP fluctuates. In most LDCs this is accomplished at the expense of other elements of the society.*

In conclusion, it is evident that progress in developing an indigenous arms production capability among the LDCs studied has been greatest in those countries possessing the broadest range of manufacturing technologies,

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* The statistical information contained in this section was taken from the United Nations Statistical Yearbook 1977, from the World Military Expenditures and Arms Transfers 1967-76, United States Arms Control and Disarmament Agency, and The National Basic Intelligence Factbook, January 1979.

the most sophisticated instrumentalities for controlling and directing investments in defense industries, and the highest levels of competence in their scientific and technical personnel. Possession of such an infrastructure does not, however, automatically imply the development of indigenous arms production by any given LDC. Mexico, for example, possesses an industrial base which compares favorably with the largest LDCs studied. Its GNP for 1977 was nearly $75 billion and its crude steel capacity was 9 million metric tons. By contrast, Argentina's GNP for the same year was $48 billion and its steel capacity was only 2.7 million metric tons. Mexico's petroleum reserves will, over time, increase its GNP and the funds available for investment. Yet Mexico has so far not undertaken an indigenous arms production to the extent practiced by any of the LDCs studied. The reasons for this probably stems from a lack of serious military threats or domestic disorders. On the other hand, judging from its overall infrastructure, if Mexico were for any reason motivated to develop an indigenous arms industry, its progress might be rapid indeed.

PATTERNS OF LDC ARMS DEVELOPMENT AND PRODUCTION

Aside from a general trend toward independence from foreign suppliers, there is no single factor which can account for the decision on the part of LDCs to develop a capability to produce their own weapons systems (see above). These decisions normally result from a variety of motivations and the emphasis given to individual factors may change over time. Nevertheless, the actual development of this capability has revealed a reasonably consistent pattern which resembles in many aspects the manner in which civilian manufacturing facilities are created. In general, the stages are:

- Arms acquisition from foreign suppliers;
- Creation of maintenance/overhaul capabilities/facilities including spare parts manufacturing through provision of technical supervision, data and training by the supplier;
- Assembly and production under license, co-production, or joint venture agreements including contracts for "turnkey" plants;
- Indigenous design, development and production.

The stages of this pattern do not necessarily succeed one another in smooth progression from the initial acquisition of foreign arms to the development of an indigenous capability to design and produce modern weapons systems. There are many stops and starts and progress is uneven. More important, it is likely that all four stages will continue to operate simultaneously as a given country moves toward independence in the achievement of an indigenous design and manufacturing capability.

It is evident, however, that total independence or "absolute self-sufficiency" will not necessarily be achieved as these stages unfold. Israel, (probably the most advanced technologically of the LDCs studied) is often cited as an example of this phenomenon. It is suggested that, if even an advanced LDC such as Israel must continue to rely on some imported components for their indigenously produced systems, there may be limitations to this pattern which will also affect other LDCs in their efforts to achieve independence in arms production.

For reasons covered in our introduction, we feel the Israeli model should be applied to other LDCs with reservations. Understandably, however, changing threat assessments, production or design problems in the indigenous product and rapidly evolving modifications of existing systems or development of more advanced systems, will all serve to maintain high levels of foreign systems acquisition and continue the utilization of foreign components. At present, it is the inability of most LDCs to meet the technical requirements of the production process at reasonable cost and in an acceptable time frame which is the principal problem. For some LDCs this limitation will always exist particularly with regard to high technology systems. Others, despite their growing competence, may elect to continue to import components or purchase systems outright. In today's highly competitive arms market this may be the most cost-effective approach and need not impair the LDC's freedom of action if the suppliers are diversified. Put differently, the percentage of foreign components in a domestically produced weapons system may not be the best criterion in deciding the degree to which an LDC faces constraints in its independence of action with regard to the production, employment or export of the system. In today's world, a weapons system or, for that matter, any industrial product which contains no foreign made components is becoming increasingly rare.

Thus, in examining these patterns, we will consider each of the stages separately, recognizing that this is a somewhat artificial treatment.

ARMS IMPORTS FROM FOREIGN SUPPLIERS

All of the LDCs studied had passed through this first phase of arms acquisition whereby virtually all of the weapons or munitions used by their forces were imported from foreign sources. Each now has at least some capability to produce a variety of arms and munitions locally. Nevertheless, they all continue to make purchases abroad of those weapons they believe they require, whether for routine force modernization or to meet specific needs related to their internal security or external threats. Therefore, as a result of their acquisitions abroad, the armed forces of these countries have become familiar with a wide variety of modern weapons systems. It is in fact this variety which accounts for the greatest shift in this first stage of arms development patterns. Whereas several years ago LDCs were generally limited to the two superpowers (whose clients they often, were), the choices today are much greater. West European manufacturers lead in competing with the U.S. and the USSR. Between 1974 and 1977 the British, French and West Germans concluded arms sales in excess of $16 billion, which nearly equalled Soviet sales for the same period. Add such countries as Italy, the Netherlands and Sweden to the West European list and the options available to the LDCs to purchase high technology weapons systems and advanced military/naval electronics are considerable. At some point, Japan may be added to these options. Capable of producing high technology systems and components of various kinds (its Type 74 Main Battle Tank carries a Nippon Electric laser range finder and a Mitsubishi Electronic ballistic computer), Japan has generally restricted its arms production to the needs of its own defense forces. Were it to change this policy, Japan could become a major source of increasingly sophisticated arms. The net result of this proliferation of arms acquisition possibilities has been to increase significantly LDCs' freedom of action and to make it less likely that either of the two superpowers can impose effective restraints on arms transfers. Also, for many reasons (access to higher quality weapons, stockpiling of war-reserve munitions, etc.), the purchase of arms abroad by many LDC's should continue as long as there is no interruption in the availability of the weapons they seek.

CREATION OF MAINTENANCE/OVERHAUL CAPABILITIES/FACILITIES

Each of the countries studied has for some time had extensive maintenance and servicing capabilities for the weapons systems it possesses. Development of a local maintenance/overhaul capability often begins through on-the-job training of indigenous personnel either locally by military missions from the supplier nation, or by sending personnel to the supplier nation for specific courses. These programs will normally be supplemented by the provision of technical data such as maintenance manuals, and at some stage, the indigenous manufacture of spare parts under license for resupply purposes. Thus, the ability to maintain, as well as operate, weapons systems of foreign origin, provides the LDC with its first layer of technical competence.

Technologically, this layer is constantly expanding as LDCs acquire more sophisticated systems on which maintenance must be performed. As their confidence and competence grow, LDC maintenance cadres experiment with modifications, substitution of indigenously made parts, etc. This experience will also lead to the application of modular technology (discussed in detail on pages) which can sharply upgrade the performance of obsolescent systems in the inventories of many LDCs. There are many examples of this process. It is being practiced extensively in Egypt as Soviet weapons are modified and also in Yugoslavia whose U.S. tanks are being upgraded.

LICENSED PRODUCTION/COPRODUCTION

This stage in the development of an independent capability for arms production has been essential for LDCs wishing to achieve indigenous design and production of modern weapons systems. It is not surprising then that each of the ten LDCs covered in this study is currently engaged in some form of coproduction, however modest the program or unsophisticated the product. These arrangements vary considerably in scope and complexity. Generally speaking, agreements between LDCs and supplier nations provide for:

- Outright purchase by the LDC of a given number of systems "ready to roll";
- Final assembly and testing of systems, components of which are provided by suppliers;
- Creation of a production facility, possibly as a "turnkey" operation; and,
- Manufacture of systems in LDC facilities with percentage of locally built components gradually increasing over time per the licensing agreement.

In most cases, licensing agreements will impose a variety of constraints on LDCs. Suppliers may, for example, insist on continuing to supply some components, particularly those with high technology content. It is often assumed, and correctly in many cases, that it is the inferior technological level of the LDC which inhibits local manufacture of certain components. This is not always true. Suppliers can insist on continuing to provide some components either because they widh to protect the technology involved or because there are important cost benefits. In addition, suppliers may impose constraints on LDC freedom to export the product or components thereof. Such restrictions normally relate to commercial considerations but can be imposed for policy reasons.

These negative factors notwithstanding, the number of coproduction agreements involving LDCs appear to be on the increase. For LDCs these agreements offer unique opportunities for technology transfer and thus they will pursue them even though they resent the constraints imposed and are aware that coproduction is normally more costly than outright purchase. For example, the Piper aircraft made in Brazil under license cost 27 percent more than the same model manufactured in the U.S. In the case of Israel, their interest in producing the U.S. F-16 and F-18A reflects a desire to acquire the advanced technology and to sustain their aircraft industry. They probably recognize that it is likely to cost more per copy.*

As competition for sales increases among supplier nations, a tendency may develop for some of the restrictions described above to be lifted or modified. Much will depend on the sophistication of the LDCs as concerns their negotiating skills and their understanding of the technologies involved. For example, Brazil drives a hard bargain in that it insists on coproduction agreements which provide for specific increases in the percentage of locally produced components, permit no restrictions on export and insure that Brazil owns the technology upon expiration of the agreement. Brazilian practices reflect the approach to coproduction taken throughout their economy. India, on the other hand, appears to have been less successful, both in the kinds of agreements it has worked out with suppliers (export constraints have been rigidly enforced by the Soviets) and in their ability to absorb the technology involved. In the case of the MIG-21, it is claimed that at least 40 percent and perhaps as much as 50 percent of the components are still imported, 15 years after the onset of production. It is not clear, however, that this is wholly a reflection on Indian competence particularly in light of these factors:

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* LDCs are not alone in their acceptance of the higher costs involved in coproduction agreements. In defending their participation in the F-16 program, officials of the Norwegian and Dutch Governments cited social and technological benefits as justifying coproduction rather than outright purchase from the U.S. at lower cost.

- India has production rights to the Soviet Tumansky R25-300 jet engine with the possibility that it may serve as the power plant for a new MARUT fighter;

- India claims that it produces 96 percent of its VIJAYANTA Main Battle Tank;

- India is considering licensed production of the Soviet T-72 whereas Yugoslavia is not considered capable of doing the same without "massive" Soviet assistance;

- India will manufacture the JAGUAR, a high technology aircraft which, in the words of its Anglo-French designers, "is ideally suited to indigenous manufacture in India, offering great benefits in technology transfer."

The South Koreans, on the other hand, with considerably less experience in coproduction ventures were not satisfied with the product of the agreement entered into with FIAT to produce an armored personnel carrier and are now considering producing one of their own design.

"INDIGENOUS" DESIGN AND PRODUCTION

In theory, this final stage of the pattern should reflect an independent capability on the part of LDCs to design and produce without foreign assistance the whole range of weapons systems needed for their armed forces and to enable them to compete for exports in world markets. In practice, no LDC has achieved this stage for the totality of its weapons requirements. Most of these studied are, however, capable of designing and producing less advanced categories of weapons for their own use and for export (ground forces systems, subsonic aircraft, small patrol craft, etc.). They do less well in their attempts to develop more advanced systems (high performance aircraft, long range or complex missiles, main battle tanks, etc.). Those advanced systems which are pursued independently by some LDCs will nonetheless involve considerable foreign assistance in both design and production. It is therefore difficult to draw a sharp dividing line between licensed coproduction and "indigenous" production. Foreign designers may be retained by LDCs to participate in the design process of an "indigenous" system, or the design of such systems may simply be modifications or copies of foreign systems. When such "indigenous" designs reach production stage, they, like systems built under coproduction agreements, will contain varying percentages of imported components. Examples of this are numerous. Argentina's TAM tank is of West German origin and its "PUCARA" counter-insurgency aircraft is powered by the French turboprop engine "Astazou." The 90 mm cannon for Brazil's highly successful, "indigenous" armored vehicle, the "Cascavel," is built in Brazil but as a Brazilian-Belgiam joint venture. The Indians claim their main battle tank "VIJAYANTA" now contains a high percentage (96 percent) of Indian-made components. It is often referred to as an example of indigenous production but in fact the tank was originally a Vickers product and built in India under license. Finally, the Yugoslav-Romanian tactical fighter "ORAO," which was designed and will be produced "indigenously" will contain Rolls Royce engines and a variety of foreign avionics.

The examples cited reveal that the line between coproduction and truly indigenous production is blurred. They also demonstrate that foreign influences, if not participation in design and production, are significant in all LDCs studied. The issue, however, is not the degree of foreign involvement. This will persist in LDCs as it has in the majority of developed countries, none of which design, develop or produce high technology weapons systems without some degree of foreign influence, assistance or involvement. This practice is nowhere better illustrated than in the experience of France in developing its "independent" strategic systems. What is important is to decide how such foreign participation should be evaluated in considering these factors.

- How much independence or freedom of action is enjoyed by LDCs in employing or marketing the systems they have produced? Put another way, in today's competitive arms market, how reasonable is it to assume that the foreign policy interests of individual suppliers can dictate the manner in which LDCs employ the weapons they produce?

- To what degree does the presence of imported components in locally produced weapons systems reflect: (a) the most cost-effective (or least-resistance) approach to the problem, or (b) the inability of the LDC concerned under any circumstances to fabricate a comparable component? Or, could the LDC, faced with an overriding need for the component, and prepared to make a priority commitment of resources, produce locally a version of the component which would permit the overall system to function at the level of effectiveness demanded by existing circumstances?

CURRENT AND FUTURE ROLES OF DUAL-USE TECHNOLOGY IN LDC ARMS PRODUCTION

BACKGROUND

In examing the relationship between those technologies which are categorized as dual-use and the production of weapons by LDCs, attention was directed at the broad range of such technologies normally present in the industrial infrastructures to which all LDCs aspire. Understandably, some emphasis was placed on examining those advanced technologies which would be a prerequisite to the production of high technology weapons systems, if such were to be attempted by a LDC. One should not, however, lose sight of the fact that most of the technologies used in modern manufacturing processes are adaptable to some phase of arms production. Conversely, almost all military technologies, from the manufacturing of gun tubes to the casting of tank turrets, can be disaggregated into dual-use technologies. Thus, those LDCs with the most developed civilian manufacturing capabilities will, in the normal course of events, likely possess many of the technologies necessary to the production of a variety of military items. For example, transportation requirements may stimulate some LDCs to develop the capability to manufacture engines for heavy duty trucks. This capability implies development of foundry techniques, machine tools, heat treating and welding; the level of electrical manufacturing needed for starters, generators, batteries; hydraulics required for transmissions, suspensions, etc. All of these and more are prerequisites to the development of the technology base required to design and manufacture armored vehicles. Analogously, in another sector, LDC communications needs are generally met by radio systems which, if manufactured by the LDC, can stimulate the gradual development of an electronics manufacturing capability.

Development of the various sectors of the industrial infrastructure has been uneven, however, from LDC to LDC. The degree of development can, of course, influence the type and complexity of the weapons systems produced by individual LDCs. For example, Egypt has a relatively well-developed, metal-working industry which is capable of rebuilding and even producing ordnance and armored vehicles. However, it has a minimal capability in the electronics industry. By contrast, South Korea and Taiwan, as a result of investments by U.S. multinational corporations, are developing an impressive capability for semi-conductor fabrication and the manufacture of a variety of civilian products embodying integrated circuitry. Significantly, integrated circuits constitute an example of civilian technology leading the military application. However, in spite of their activity in the semi-conductor field, there does not yet appear to be indications that either South Korea or Taiwan have developed a capability to produce military electronics which would embody integrated circuits. The fact that the civil sector leads the military in this instance reflects an increasingly common phenomenon among LDCs as the latter press their demands for technology transfer.

How well LDCs can absorb these manufacturing technologies and apply them to military systems depends, of course, on their reserves of trained manpower and the related managerial, scientific and technical skills. The evenness of industrial development and the rate of technology transfer will also be a function of the central planning, economic and financial control mechanisms described above in the section on LDCs' infrastructure. Assuming the existence of an adequate infrastructure, and the will and resources on the part of LDCs to acquire civilian technologies, the latter are readily available from developed countries (and also from several of the more advanced LDCs). Civilian technology acquisition takes many of the same forms described above for military technology, i.e., licensed assembly, joint ventures, co-production, "turnkey plants," etc. Controls on the export of civilian technologies to LDCs by the developed countries vary. The United States, under its export control regulations requires validated export licenses on many of the DUTs of interest, but these are routinely approved in the majority of cases affecting LDCs even when the item is on the Coordinating Committee (COCOM) List. Other Western industrial nations are more flexible in their administration of export procedures and are guided more by purely commercial considerations in their decisions on the release of civilian technologies to LDCs.

Even as the sophistication and complexity of the industrial infrastructures of individual LDCs progressed, and their ability to absorb and apply advanced technologies to the manufacture of civilian products improved, this did not imply the automatic application of these technologies to the production of advanced weapons. In many cases, traditional military assistance programs or other methods for acquiring weapons systems made it unnecessary, as well as unprofitable, for LDCs to base their arms acquisition and production programs on the conversion of civilian technologies to military applications, i.e., to exploit their "dual" utility.

Concerns for the "dual-use" aspects of technology have, of course, long existed with respect to exports to Communist countries. Because there is an embargo on the transfer of military technology to these countries, the need was felt, and expressed in the COCOM arrangements, to deny to Communist countries those civilian technologies which could enhance their military potential. Applications of the COCOM arrangements is not easy, involving as it does the balancing of commercial versus national security interests by the participating nations. In the United States there has been considerable public debate on this issue. The possibility of the USSR benefiting militarily from technology transferred to it by the United States has been raised with regard to the Kama River truck plant, the sale of grinders for precision, miniature ball-bearings, computer systems for any purpose and the transfer of product design and manufacturing technology for oil drilling tools.

Similar concerns are now emerging, primarily in the United States, with regard to LDCs' potential for exploiting dual-use technologies for military purposes. Such concerns arose initially with regard to nuclear proliferation as it became evident that technologies related to the peaceful uses of nuclear energy could be applied to development of a nuclear weapons capability. The manner in which Pakistan, spurred on by India's testing of a nuclear device in 1974, apparently proceeded to create its own "Islamic Bomb" contains most of the ingredients of a classical case of technology acquisition, both on the overt level (the French reprocessing plant) and the covert (operation of Pakistani purchasing missions in Western Europe).

Until the relatively recent past, this applicability of civilian technologies to non-nuclear weapons systems had not evoked the same concerns. By 1978-79, however, a combination of circumstances emerged which changed this view, at least in the United States. They were:

- Intensification of the growing trends toward independence in arms acquisition by LDCs as a result of U.S. policies favoring restraint in arms sales to the Third World and denying arms to LDCs considered in violation of human rights. Since such policies of restraint have not necessarily been applied to the sale of DUTs and their associated products, DUT acquisition appears to present a viable alternative to counter such policies;*

- Recognition of the possibility that a growing number of LDCs were developing industrial infrastructures and arms production capabilities which could result in the development of weapons systems having a destabilizing effect in their regions. In this regard, the greatest concern was felt for nuclear delivery systems, but in the absence of nuclear weapons, a number of other advanced air, ground and naval systems could also threaten regional balances.

It is evident, then, that there is a progression in the application of dual-use technology to military systems, from the simple to the more complex and capable. Unfortunately, there is no clear pattern to this progression which can be tracked with confidence. There are, however, certain paths we believe the more advanced LDCs will follow as they work to improve their weapons inventories in the future. These will be examined below, with special attention to the role dual-use technologies will play in their development.

DUAL-USE TECHNOLOGIES IN FUTURE LDC ARMS PRODUCTION

Because the spread of technology is a worldwide phenomenon, widely regarded as economically and socially beneficial, LDCs, with few exceptions, are acquiring technology at increasing rates and will continue to do so in the future. We have noted heretofore that the LDCs in this study are distinctly heterogeneous in their economic development, level of sophistication in science and technology, capability of their industrial infrastructure to absorb technologies transferred from industrial nations and in their policies and perceptions regarding preferred military forces. In these circumstances the rates of technology application and military production will vary even though the general learning experience in acquiring new

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* See Volume III of this series for a case study which provides a seemingly related example, A Study of the Exploitation of Dual-Use Technologies: South Korea (Confidential).

technologies has been somewhat similar for all LDCs (weapon system purchase, overhaul and servicing, parts manufacture, and licensed production to the ultimate indigenous manufacture of the complete weapon system). We would expect the same in the future. Exploitation of dual-use technology in this process is ubiquitous, even benign. The dual-use technologies involve an array of technical areas that encompasses mechanical, electronic, material, chemical and other technology applications in both civil and military product areas. Throughout the world, the transfer and diffusion of such technologies is natural and widespread and it is difficult to isolate specific instances of exploitation in terms of specific weapons uses. It appears, however, that LDCs are likely to select one or more of the following among alternative approaches for achieving improvements in their weapons inventories:

- Upgrading of existing weapons.
- Producing weapons embodying proven technologies.
- Producing advanced weapons.

Each of these alternatives implies a certain level of industrial sophistication and know-how in the various weapons technologies. Each alternative is likewise implicitly compatible with the LDC industrial infrastructure and the character of the arms manufacturing that an LDC may undertake. Moreover, it is also possible for certain LDCs to be pursuing more than one of these paths simultaneously as they expand their technological base.

The potential of dual-use technologies—to the extent that civil and military applications are functionally similar—to be adapted and applied in this process is a vital factor affecting not only the quality and hence the military significance of the weapons thus produced but the rate at which those weapons may appear and thus advance the military power of the LDC producing them. Some dual-use technologies in functionally similar civil and military applications are indicated in Table 4. In most instances the similarities between civil and military applications vastly outweigh the differences in terms of the technology and industrial arts that may be involved. For example, gas turbine engines designed for civil transport aircraft such as the GE-CF-34 are physically identical to the engines used to power the Fairchild A-10 and Lockheed S3A except for certain control features and the exterior envelope. Similarly, the British Rolls Royce SPEY in its

TABLE 4. SOME DUAL-USE TECHNOLOGIES
IN FUNCTIONALLY SIMILAR CIVIL & MILITARY APPLICATIONS

Technology Area	Civil Applications	Civil Technologies	Military Technologies	Military Applications
Materials*	Directed Energy uses	Windows/Mirrors	Windows/Mirrors	H. E. Lasers
	Jet Engines	Turbine Blades	Turbine Blades	Jet Engines
Mechanics	Aircraft Navigation	Gyros & Accelerometers	Gyros & Accelerometers	Inertial Navigation
	Light, strong structures	Composite Mat'ls	Composite Mat'ls	Light, strong structures
Electronics*	Air Traffic Control	Radar	Radar	Bomb/Nav. Avionics
	Computers	Integrated Circuits	Integrated Circuits	Computers
Energy	Remote Energy Sources	Batteries	Batteries	Remote Energy Sources
	High Energy Physics	Particle Beams	Particle Beams	Aerospace Weapons
Software*	Computer Programming	Software Design	Software Design	Computer Programming
Chemical Processes*	MOS/LSI	Vapor Deposition	Vapor Deposition	MOS/LSI
	Tires	High strength Polymers	High strength Polymers	Tires
Geodesy	Navigation	Satellite Positioning	Satellite Positioning	Navigation
	Mapping	Photogrammetry	Photogrammetry	Mapping
Oceanography	Ocean Survey	Acoustic arrays	Acoustic arrays	ASW
	Ocean Surveillance	Radar Signal Processing	Radar Signal Processing	Anti-ship Missiles
Atmosphere/Space	Atmosphere Probes	Rocket Design/Mfr	Missile Design/Mfr	S-S Missiles
	COMSAT	Space Launch	Space Launch	MILSAT

* Technology areas where currently available civil technology tends to lead military technology in certain aspects of the applications cited.

civil version (RB-163) is used in a variety of transport aircraft such as BAC-111, TRIDENT DH-121, Grumman Gulfstream II and the Fokker F-28. More recently Romania, which has engaged in aircraft coproduction with Yugoslavia, has been licensed to build the SPEY to power the BAC-111s it is also constructing under license. This civil version served as the forerunner of the military RB-168 engine. The latter is used in the British versions of the F-4 and is now going into production in the PRC. Fabrication and assembly of the "hot section" turbine rotors and blades is the common but critical technology here whether civil or military engines are to be produced. In another area, successful manufacture of integrated circuits depends on the techniques of mask fabrication and vapor deposition and quality control inspection whether the applications are in civil communications or military computers.

Technology areas where civil applications are known to lead the functionally similar military applications are indicated by an asterisk in Table 4. This does not necessarily mean that the civil technology offers an immediate military advantage but it does indicate specific areas where such advantages are likely to occur. The technological character of the LDCs industrial capabilities obviously must be weighed rather carefully in assessing the real value of ready access to such dual-use technologies in terms of the LDCs' capabilities to absorb, manage and deploy those technologies in a military sense.

Upgrading of Existing Weapons

The simplest, most achievable and often the most economical approach for LDCs to use available technologies to best advantage is to enhance the performance of weapons systems already in their possession. Often these systems could be considered obsolescent by superpower standards, however, the upgrading is readily possible through direct purchase or licensed production. The fact that upgrading constitutes an important aspect of the arms trade conducted between LDCs and numerous West European suppliers suggests that LDCs' perceptions of "obsolescence" may differ. For example, a great deal of the upgrading of arms by the LDCs studied involves the U.S. M-48 and the Soviet T-55 tanks, the designs of which have their origins in the immediate post-World War II period. By this process, LDCs are able to achieve expansions of their inventories in weapons systems which meet their defense needs regionally and also to dispose of their surplus arms to even less developed countries. In the case of the latter, the upgrading feature adds to their saleability. Subsystems or components such as fire control for air defense or homing devices for air-to-ground weapons for example, may be purchased directly from outside suppliers and incorporated into existing weapons. In many cases, this upgrading will be accomplished by utilizing modular augmentation techniques (discussed below in greater depth). If the industrial infrastructure can absorb the new technology upon which these enhancement subsystems or components are based, the LDCs may choose to produce such items themselves through licensing and eventually—having absorbed the technology—through indigenous manufacture or even redesign to accommodate local conditions. To date, only Israel has demonstrated this capability in any depth, but India's electronic industry is developing in this direction.

Some applications of dual-use technologies to upgrade existing weapons are shown in Table 5. The technologies underlying the subsystems or components—although they have civil uses—are in these applications reasonably well identified with the weapons components which are traded and/or licensed as such. Hence the notion of applying dual-use technology is not primarily the issue here, because most upgrading can be accomplished directly through purchase or licensed production. Of course, those LDCs which do absorb and apply the technologies to advance their own product lines are also capable of moving to a more advanced state of arms manufacture.

Weapons Production with Proven Technologies

Some LDCs choose to produce modern weapon systems which do not press the state of the art but instead reflect the best of the 1950s' and 1960s' technology. Among the weapons systems produced by LDCs today which are sufficiently modern to be useful include India's MIG-21 fighter aircraft, or its VIJAYANTA main battle tank, Taiwan's F-5E, Argentina's IA 58 PUCARA, or Brazil's CASCAVEL armored car. In the case of the French MIRAGE fighter aircraft, various models already are being produced by many countries around the world of which some, such as South Africa, are among the LDCs of interest here. Naval vessels of the 1960s' design vintage are also being built by LDCs as evidenced by Argentina's construction of the Type 42 guided missile destroyer.

TABLE 5. UPGRADING EXISTING SYSTEMS

WEAPON SYSTEMS	DUAL-USE TECHNOLOGIES	APPLICATIONS
Aircraft Systems	Computers/Software Electronic Components Avionics Integration Inertial Navigation	- French Thomson-CSF VE 110 CRT heads-up display to enhance navigation and fire control; retrofit aircraft such as A-4 SKYHAWK, CRUSADER, FOUGA 90, AND MACCHI 339.
Military Electronics	Integrated Circuits/LSI Electronic Components Optics Laser Materials Microprocessors	- Addition of new radar system to Chilean HAWKER HUNTER aircraft which provided all-weather capabilities. - Fire control upgrade for tanks; add laser range finders. Examples: Yugoslav licensed production of ISKRA/Ericsson UAL 11201 system used in upgrading Egyptian T-55s. Israeli development of ELBIT microprocessor-based fire control computer. - Electronic warfare; SELENIA-SL/ALQ-234 jamming pod for Egyptian MIG-21 upgrade.
Missile Systems	Infrared Detectors Propulsion Charge-Coupled Devices (CCD) Electronic Contrast Guidance	- Air-to-Air (AAM) missiles; IR homing missiles such as a U.S. SIDEWINDER (AIM-9), French MAGIC (R-550) or Israeli SHAFRIR. - Air-to-Surface (ASM) missiles; French AS-30 "ARIEL". - Range extension of battlefield missiles (SSM) by means of high energy propellants and upgraded rocket motor performance.
Ground Vehicles	Engines (propulsion) Explosives (shaped charge) Solid Propellants Electronic Imaging	- Upgrading maneuverability, range and endurance of tanks such as U.S. M-48, British CENTURION, or Soviet T-55; substitute modern diesel engines. - Anti-tank missiles such as U.S. TOW, British SWINGFIRE or German COBRA significantly upgrade ground vehicle systems.
Ships (combatants)	Gyros/Accelerometers Inertial Navigation Precision Guidance Computer Terminal Homing Software	- Enhancement of guidance systems of Airborne (AAM) Shipborne and Surface (SAM/SSM) missiles by incorporation of components such as the British MSDS semi-active homing head; upgrades missiles including SIDEWINDER, SPARROW, SEA DART; retrofitting of Egyptian OSA, and KOMARS with Marconi SAPPHIRE fire control systems.

Choosing weapons of a moderate capability level whose design and manufacture are well within the boundaries of the technologies and industrial arts required to make them can be a very useful and effective approach to achieving arms production goals. Such weapon systems are not overly sophisticated and hence may cause less alarm to one's neighbors. Such weapons may not be able to perform near the limits established by big power weapons but they can be economical to acquire and to maintain and they represent a low technical risk in the commitment of investment funds. Effectiveness against neighboring threats is relative and, for most LDCs, moderate capabilities may be more than adequate except in particular areas where certain superpower interest may have provided unusually advanced weapons capabilities. By and large the dual-use technologies that enter into the manufacture of modern weapons at the 10-20 year old state of the art are (with few exceptions) already widely available in the industrial world. The basic processes such as casting, forging, pressing, welding, machining, assembly, etc., and most of the special arts involved in the application of these and other technologies to modern weapons manufacture are already familiar and readily absorbed. In fact, the LDCs availing themselves of these dual-use technologies will have the same advantages that newcomers to a developed field of endeavor always have, i.e., they will benefit from mistakes of others and learn the shortcuts and preferred operations rules immediately instead of the hard way. Application of less advanced technology can, in fact, prove to be an important contribution to the evolutionary improvement of the industrial infrastructure. Most LDCs with the possible exception of Israel, India or South Africa would probably prefer to avoid the risks and uncertainties of attempting "threshold state-of-the-art" arms manufacture.

With few exceptions dual-use technologies are widely available for the manufacturing processes involved in the manufacture of weapons systems with proven technologies. The LDCs examined in this study are without exception ready to absorb some or all of the weapon systems technologies required for this level of manufacture. In almost every country the technologies required can be assimilated through licensing or, for the most advanced LDCs, through indigenous reproduction. The arms thus produced may in fact have a bigger market than more sophisticated, more expensive, more "difficult to make" products, particularly in other LDCs. Prime examples of the export potential of moderately advanced weapons systems are Brazil's BANDEIRANTE aircraft, which, suitably modified, can serve in a number of military roles. Brazil has also become an exporter of armored cars like the CASCAVEL which is popular in the Middle East and North Africa and appeals especially to states which combine military and police internal security operations.

Weapons embodying proven technologies can also be augmented by the same type of upgrading via the modular techniques used for improving the effectiveness of existing weapons. An LDC that chooses to achieve its arms goals through the production of modern but not advanced weapons systems, modified with selected subsystems and components representing new technologies (e.g., materials, electronics, computers, propulsion, guidance and navigation), may be very close to an optimum weapons policy. Details of that policy of course depend on the regional situations and political and economic factors previously discussed.

Advanced Weapons Production

A few of the LDCs may choose to achieve 1970-1980's state-of-the-art performance via indigenous production of truly advanced weapons systems. Typical aircraft and missile systems that are candidates for LDC advanced weapon systems production are the following:

- Aircraft
  - proposed Israeli (ARYEK) new generation fighter
  - F-16, F-18 (USA)
  - Panavia's TORNADO (European)
  - Anglo-French (JAGUAR)
- Missiles
  - SAM: PATRIOT (USA)
  - Shipborne SSM: GABRIEL MARK 3 (Israel)
  - Battlefield support: PERSHING II (USA) PLUTON (and its derivatives) France

For their manufacture, weapons systems of this kind would require the existence of a broad range of technological and industrial facilities available to the LDC plus know-how acquired over many years. Among the new weapons developments of the 1970's, some significant advanced technologies have emerged as illustrated in Table 6. Some, like the transducer techniques, span decades of development and broad participation while others like the microprocessor

TABLE 6. SOME SIGNIFICANT ADVANCED WEAPONS TECHNOLOGIES AND THEIR APPLICATIONS

Weapons Applications / Technical Areas	Precision Guided Weapons "One Shot-to-Kill"	Remotely Piloted Vehicles "RPV"	Day-Night Operations "Rock-Around-the-Clock"	Target Detection & Acquisition "I SPY"	Command, Contro Communications "C^3"
Materials	Shaped Charge	Composite Materials	Lasers	CCD	Fiber Optics
Mechanics	Solid Propellants	Gyros/ Accelerometers	Armor	Acoustic Transducers	Space Platforms
Electronics	Radar/IR Seekers	Micro-processors	Communications	LSI/VLSI	Imaging
Energy Sources and Conversion	FAE	Small Jet Engines	Propulsion	Focal Plane Arrays	Energy Storage
Computers	Precision Guidance	Remote Control	Inertial Navigation	Multi-sensor Correlation	Distributed Processors
Software	Terminal Homing	Correlation Guidance	Fire Control	FFT Processing	Information Storage/ Retrieval

* *Most technologies have multiple applications and in more than one technical area.*

arts are new and much less widely shared. Most but not necessarily all of the technologies in Table 6 could be dual-use technologies,...that is both civil and military applications could exist. However, advanced technologies at the threshold state of the art typically are represented by unique devices and practices—either civil or military—that limit their accessibility by LDCs. For example, the composition and thermal treatment of composite materials during their manufacture, the unique core materials used in vacuum casting, and the software for LSI design and manufacture constitute unique elements in their respective industrial practices. If even one of these is lacking the weapon system requiring that component could not be built unless a substitute was found. Furthermore, experience shows that systems integration of advanced weapons involving threshold state-of-the-art components is in itself a critical technology by virtue of the complex design/redesign problems, substitution, alternatives, modifications and compromises that normally accompany such advanced weapon systems manufacture.

Among the more critical of the dual-use technologies implied to the weapons systems examples above are the following:

- Large Scale Integrated Circuit Fabrication
- Computers and Software
- Turbine Engine Manufacture (hot section)
- Microwave Solid-State Devices
- Composite Materials
- Numerically Controlled Machine Tools
- Advanced Joining Techniques.

Only a few of the LDCs studied would consider indigenous manufacture of these advanced systems. Except for Israel, and to a lesser extent India and South Africa, none of them presently have the capability to absorb and exploit effectively the combination of dual-use technologies which are essential to construction of these systems. It is not, however, the availability of such technologies which alone imposes constraints on the production of advanced systems.

As indicated, each of them, in one form or another, is available in the industrialized world. For example, one of the most complex technologies, ceramic turbine manufacture, is now available on a commercial basis as a result of the affiliation of the Howmet Turbine Components Corporation with the European Pechiney-Ugine-Kuhlmann Group. Rather, it is the degree to which individual LDCs reach the higher technological levels whereby they can absorb such technologies and apply them to the complex problems of systems construction and integration posed by these advanced systems. On the other hand, over time, most of the LDCs are expected to attain some appropriate level and will have acquired and begun to utilize the technologies in question, as in the case of South Korea which has a rapidly developing integrated circuits industry supporting its requirement for microelectronics.

MODULARITY AS A TECHNIQUE OF UPGRADING

In our examination of the development of LDC arms production, we noted the importance of upgrading weapons systems present in the inventories of LDCs and the extent to which modularity played a role in such upgrading. In fact, the concept of modularity has been widely used in upgrading the adaptability, flexibility and responsiveness of weapons systems to meet the uncertainties of modern warfare. By using modular or "building block" techniques it is possible to substitute or add on components which improve performance and to employ in this process technologies which fall short of state of the art yet still deliver a level of upgrading which can markedly alter the potential effectiveness of the system. Modular upgrading in practice can occur in several different modes that encompass varying degrees of component substitution, component add-on and component capability extension in order to achieve the desired performance increment. Interchangability of weapons complements which involves the practice of using a land, sea or air vehicle as a delivery platform for a variety of ever improving weapons is a familiar example of the upgrading technique. At the same time, modularity in upgrading extends to interchanging other components of the system such as power plants, communications units, fire control and electronic warfare elements.

Upgrading can now accomplish more sophisticated purposes than in previous decades. Table 7 presents, in a general way, the particular advantages which might be achieved by utilizing 1970's technologies in the upgrading

TABLE 7. MODULARITY AS A WEAPON SYSTEM UPGRADING TECHNIQUE

(SOME TECHNOLOGY EXAMPLES)

MODE	APPLICATION	1950's-1960's TECHNOLOGIES	1970's TECHNOLOGIES
Component Substitutions	Precision Weapons Delivery	Bombing/navigation on-board digital computers and weapons checkout for improved delivery accuracy and reliability.	Digital flight control and fire control systems; electronically-agile radar for terrain following/avoidance, mapping, inertial navigation and precision weapons delivery (such as the correlation guidance systems, e. g., TERCOM).
	Tactical C^3	Multiband radio/microwave solid-state communications systems with transistorized switching, magnetic recording, multiplexing.	Digital distributed microprocessor voice/data communications utilizing optical frequencies, fiber optics, LSI, small size and large bandwidths.
	Propulsion	Axial multistage ~15000+ lb thrust turbine engines such as the JT3 (Boeing 707 and 720, DC-8) and its military versions J57/TF33 (B-52, KC-135, F-100/101/102).	High thrust/weight 15-30000+ lb.thrust high performance turbofan engines such as the F-100 (F-15/16), TF-30 (F-14) or civil JT-8 versions (Boeing 727, 737, DC-9).
Component Add-ons	Compatible Weapons Families	Multiple weapon payload configurations, e.g., rockets, missiles, bombs, chemical and fuel options for pre-mission selection.	Interchangeable mm wave/IR imaging contrast guidance sensors for all-weather standoff delivery of families of tactical missile/"smart bomb" weapons.
	Survivability	Electronic Warfare pods (or packages in ground systems) for ELINT/SIGINT, EW reconnaissance countermeasures (typically the ECM "black boxes" for tactical aircraft operations.	Pod-mounted multimode receiver/jammer systems for EW with digital wideband automatic coverage of the frequency spectrum, independent ram-air electrical power, (hostile radar identification) and modular design for easy maintenance (e.g., the ALQ-234 produced by Selenia in Italy for the MIRAGE aircraft family)

(CONTINUED ON NEXT PAGE)

TABLE 7. MODULARITY AS A WEAPON SYSTEM UPGRADING TECHNIQUE (Continued)

(SOME TECHNOLOGY EXAMPLES)

MODE	APPLICATION	1950's-1960's TECHNOLOGIES	1970's TECHNOLOGIES
Component Capability Extension	Threat Responsive Weapons	Multiple payloads, hard-point mounts and weapons controls for a range of types/sizes of rockets, missiles, bombs, electronic warfare and/or fuel (e.g., F-105 fighter bomber payloads).	Modular bomb/submunition dispenser systems for alternative target effects including fragmentation, hard-point, FAE, or GP against armor, personnel fixed targets; (e.g., wide-area anti-armor munitions).
	Propellant Upgrading	High Isp propellants for increased velocity, range and payload.	High burning rate propellants ,or low radar/IR cross-section visibility of tactical missiles.
Manufacturing Capability Extension	Efficient Metalworking	Numerical control machining for multidimensional multi-axis metal-working (especially in engine manufacturing).	Microprocessor and adaptive control of metal-forming and other operations for manufacturing precision, flexibility and quick response (as in production of turbine blades, aircraft/missile structures).

process as compared with those of the 1950's-1969's. Clearly, an LDC with a capability to absorb the current state of the art could gain significantly if this capability were applied to its modular upgrading programs. Nevertheless, it is evident from Table 7 that even the "vintage" technologies of earlier periods can have impressive results when incorporated in systems upgrading. This is most notable when an obviously obsolete or obsolescent weapons system is sharply upgraded in terms of ordnance, fire control, power plant, etc.

Because upgrading permits a nation to prolong the life of a variety of weapons systems already in its possession, it offers an attractive, cost-effective approach to improving overall force effectiveness. These techniques are not restricted to LDCs, however, as budget constraints force many of the advanced industrial nations to upgrade rather than procure new, advanced systems (the U.S. B-52 strategic bomber is a prime example). The practice has been even more extensive in Western Europe and it is among the West European arms suppliers that LDCs have found their best sources for upgrade modules for air, land and sea systems. To our knowledge, no breakdown exists of arms sales figures which would indicate how much of the total is for new systems and how much for retrofit or upgrade components. It is our impression, however, that the latter occupies a significant place in arms transactions for many West European countries. At the same time, among the LDCs studied, Israel has developed a substantial number of products across a relatively wide spectrum of mature technologies which can upgrade existing systems as has India. Others such as Brazil and Yugoslavia have produced some examples, primarily in cooperation with industrialized countries.

Air Systems

The permutations of upgrading to improve the combat effectiveness of weapons systems are infinite. Some idea of the possibilities inherent in these techniques can be obtained from the discussion below of their application to air, land and sea platforms and systems. Modularity appears in its most ubiquitous form in the optional payloads of the tactical aircraft found in LDC forces. Here bombs, rockets, guided missiles, electronic warfare or reconnaissance modules, fuel stores or other interchangable internal or external payloads completely alter the mission capabilities of the aircraft platforms.

Modularity reaches its highest level of sophistication in electronic systems wherein third or fourth generation digital computers manage several functions. The French Thomson-CSF VE-110 "head-up" display provides navigation for all-weather interception, air-to-air missile and gunfire ranging and control as well as air-to-ground attacks using either conventional weapons or guided missiles. It is used to upgrade various combat aircraft, many of which, such as the MIRAGE III, are used by LDCs. Improvements occur frequently in air-to-air or air-to-ground missiles which incorporate terminal homing techniques (these are at least fifteen years old) to boost the target kill capability of older aircraft by as much as tenfold. An example of this technique is found in the development in the mid-70s by Great Britain's Marconi Space and Defense Systems of a 5-inch, micro-miniaturized missile guidance head fitted with a mini-computer using state-of-the-art LSI technology. It can be used to upgrade a number of air-to-air and air-to-surface missiles. Another example of electronic upgrade which can improve aircraft survivability in air-to-ground attack is the electronic warfare jamming pod (ALQ-234) produced by Italy's Selenia. This pod, which was under consideration for upgrading Egypt's MIG-21s, as well as the MIRAGE series, contains a programmable digital processor for identification of hostile radars, and for other functions.

Land Warfare Systems

Land warfare systems have also received considerable attention in the upgrading process. Because the main battle tank is an expensive item, it is a primary candidate for undertaking improvements through application of modularity. Many LDCs have tanks of the M-47/48 and T-54/55 vintages in their armored forces and have undertaken to upgrade them in various ways. The fire power may be increased by improving the main gun; the Israelis substituted British 105 mm guns (made in Israel) for the 100 mm guns on the Soviet T-55s they captured in the 1967 war. Improvement in the calibre and velocity of guns on existing armored vehicles is a common practice in many LDCs. In addition, the fire control systems are upgraded. The Yugoslav "ISKRA" firm produced laser range finders for the Soviet T-55s in the Yugoslav forces. The same firm is believed to be producing the Swedish Ericsson UAL 11201 laser fire control system under license which will be sold to Egypt for its Soviet tank retrofit program. Tanks can also be given night vision capabilities as part of the upgrading process. For example, British Rank Ltd. produces a night/day vision system which incorporates a laser range finder and is designed for upgrading a variety of tanks including both the U.S. M-48 and the Soviet T-55. While much of this equipment continues to be produced in Western Europe, as the Yugoslav example demonstrates, LDCs are keenly aware of the advantages that accrue from upgrading armored vehicles and will begin to produce their own systems. As usual, the Israelis appear to lead with the fire control system designed by Elbit Computers Ltd. for the Israeli MERKAVA tank. It includes a state-of-the-art microprocessor which performs ballistic computations for the main gun. An additional approach to tank upgrade is the substitution of more efficient and powerful engines. In U.S. M-48 tanks, original gasoline engines have been replaced by diesels.

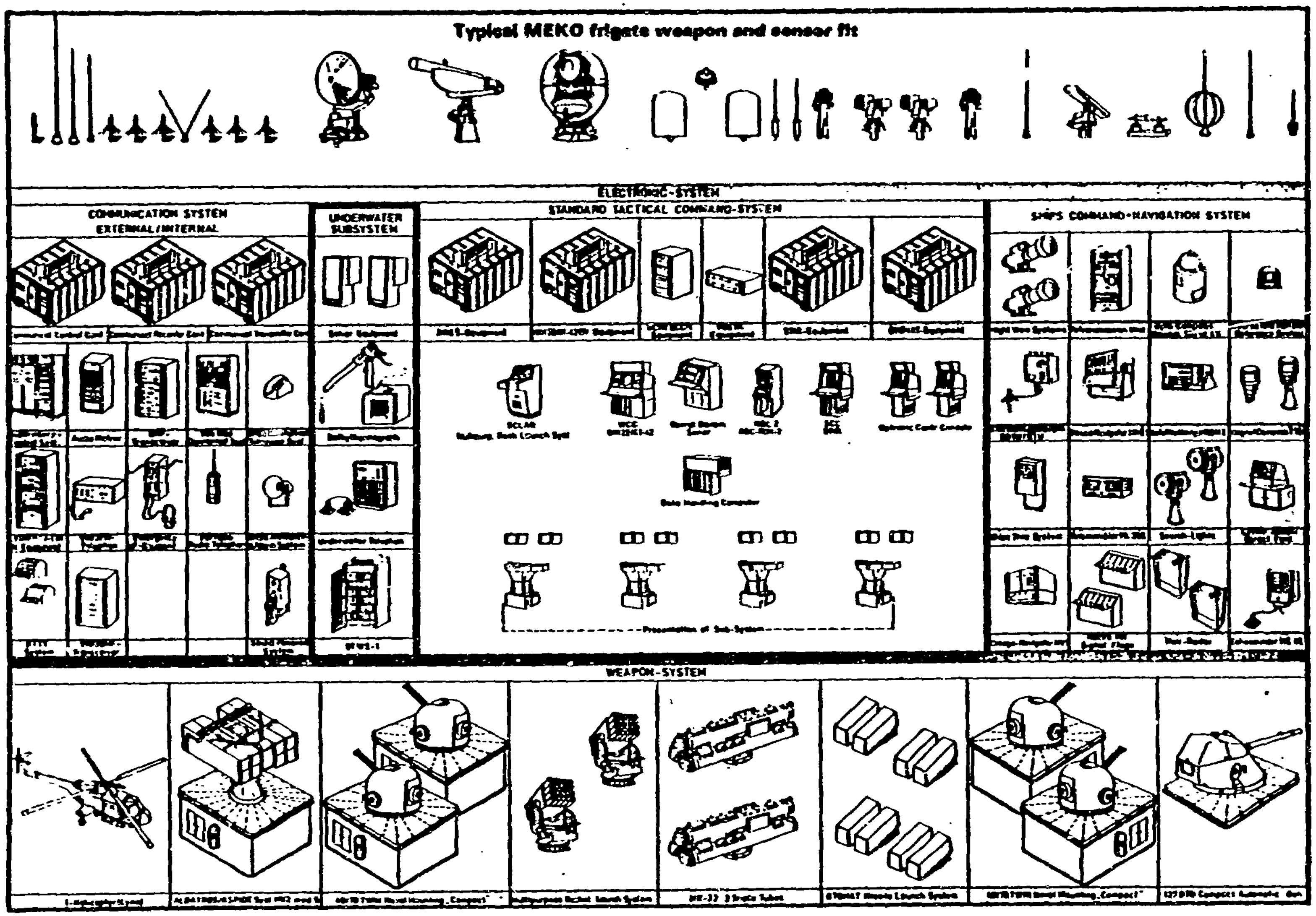
It is not only armored vehicles that benefit from modular upgrading but other ordnance as well. For example, Singapore produces a laser range finding system for field artillery under license to Avimo Ltd. in the United Kingdom. India is engaged in a coproduction venture with Contraves of Switzerland in which Bharat Electronics produces the fire control radars for the LP-70 AA system produced and marketed by Contraves.

Finally, it is expected that land warfare capabilities of LDCs will profit from the advantages of the RPV in battlefield reconnaissance. Several are made for export by West European countries. Belgium, for example, markets an export version (ASMODEE) of an RPV originally designed for NATO use which has an 80 km range, is powered by a turbojet engine, and is capable of real time TV and infrared imaging. A key factor in development of RPVs is the availability of reliable, low cost jet engines of the appropriate size, i.e., between 150 and 500 lbs. thrust. Israel now claims this capability in the small engines manufactured by TAT Ltd.

Naval Systems

Sea-based systems employ a high degree of modularity in original design thus making them particularly attractive as candidates for continuous upgrading as weapons improve. Perhaps the most interesting recent example is the West German designed frigate MEKO 360H which was under consideration for licensed construction by Argentina (See Table 8). This ship has been ordered by other LDCs. A key

TABLE 8. MEKO 360H FRIGATE — A MODULAR CONCEPT



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aspect in its favor is the high degree of modularity which permits a variety of C^3 to be added in a significantly cost-effective manner by lowering the time required for removal or installation. Among the weapons systems the MEKO version designed for Argentina would mount are the OTOMAT and EXOCET SSMs and the ASPIDE SAM. It would be possible of course to substitute other systems such as the HARPOON, PENGUIN or GABRIAL SSMs. The latter, now in its third version (Mk-3), produced by the Israelis, remains the only shipborne SSM available in the West which has been tested in combat. Even if Argentina does not proceed with construction of the MEKO system, the modular concepts it incorporates are still applicable to the vessels produced by many LDCs ranging from a large variety of fast patrol and missile boats to larger combatants such as the LEANDER class frigates being built by the Indians under license.

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CONSIDERATIONS IN CONTROLLING KEY DUAL-USE TECHNOLOGY PRODUCTS

As stated several times in earlier sections of this paper, LDCs can now purchase from an increasingly larger number of extremely capable suppliers any number of complete weapons systems or the modular components with which such systems can be upgraded. LDC customers can be expected to continue to purchase whole systems, particularly of the more sophisticated variety, even though they will press for licensed production as in the case of the Indians with the JAGUAR and the Israelis in their approach to acquisition of the F-16. Similarly, in the case of modular subsystems, most LDCs would prefer or may find it more convenient and cost-effective to buy military components or products with which to carry out retrofit programs. Even in this case, however, some LDCs have demonstrated the capability to produce some of the subsystems in question. In sum, as long as military products can be obtained freely, without constraints in their use imposed by the seller, and if the LDC customer has reasonable assurances that delivery schedules will be adhered to, and spare parts made available, many LDCs will continue to purchase systems and subsystems abroad. They recognize that if these conditions can be met, it is less expensive to purchase advanced military systems abroad than to invest in the infrastructure needed to produce them at home.

Despite this, we believe most LDCs will remawn firm in their determination to achieve the maximum degree of independence they can in support of whatever military posture they feel is required for their national security. This viewpoint was recently expressed by the Israelis in explanation of the development of their own indigenous arms industry,* and while it is certainly overstated (in view of

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* "Israel's defense and electronics industries were born out of necessity, the results of a series of embargos such as the one French General de Gaulle imposed after the 1967 Six Day War. Israel decided it would be virtual suicide to leave production of vital equipment in non-Israeli hands and moved full force towards setting up an ultra-sophisticated manufacturing capability, fast gearing itself to American standards as U.S. material replaced the French equipment in Israeli stockpiles." Special Israel Advertising Section, Aviation Week and Space Technology, October 8, 1979.

their continuing dependence on the United States), it is probably a fair reflection of the attitudes one would still encounter in the other LDCs under study. Thus, if for whatever reason multi-national controls were successfully imposed on sale of certain military products to one or more LDCs, the LDCs in question might seek to circumvent them. One approach, of course, would be to produce the required systems themselves assuming that the capability existed to do so. This would imply the ability to apply the various critical technologies discussed earlier and to do so without foreign assistance. Again, as we have implied earlier, there are almost no LDCs that could sustain a significant production effort of essential weapons systems if all foreign support were denied. In other words, it would be extremely difficult to design and produce new systems (multi-role tactical aircraft, main battle tanks, missile frigates, etc.) without foreign assistance.

On the other hand, it would be possible to upgrade or modify existing systems in ways which might be regionally destabilizing. The South Korean efforts in connection with the Nike-Hercules missile system are perhaps an extreme example of this.* In some areas, it might suffice if one LDC were to suddenly develop an all-weather capability for its fighter aircraft and a night/day capability for its tanks. Because upgrading might be possibly significant in some areas, we have examined retrofit modes to determine whether it might be possible for some LDCs to adapt certain dual-use technology products to this purpose. These are civil products which are not now normally controlled to LDCs even though in most cases their export to Communist countries would not be permitted. Table 9, below, suggests several possibilities but it should be emphasized that these are extremely tentative selections. We do not know in most cases how well some of these products would perform in military roles nor are we sure of what would be involved technically in adapting these products to military purposes and integrating them into the weapons systems as a whole.

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* See Volume III of this series.

TABLE 9. SOME KEY DUAL-USE TECHNOLOGY PRODUCTS WHICH ARE NOT GENERALLY CONTROLLED TO LDCs

- CIVIL INERTIAL NAVIGATION SYSTEMS CAPABLE OF USE ON:
  - Military Aircraft
  - Cruise Missiles
  - RPVs
  - Ballistic Missiles (mods needed)
  - Naval Craft
  - Land Navigation System for Tanks
- CIVIL TURBOJET/TURBOFAN/TURBOSHAFT AIRCRAFT ENGINES CAPABLE OF USE ON:
  - Military Aircraft
  - Cruise Missiles
  - Attack Helicopters
  - RPVs
- CIVIL MARINE TURBOSHAFT/DIESEL ENGINES AND GEARBOXES CAPABLE OF USE ON:
  - Naval Craft
- CIVIL HIGH POWER DIESEL ENGINES AND TRANSMISSIONS CAPABLE OF USE ON:
  - Tanks
  - Armored Cars
  - APCs
- CIVIL NIGHT VISION DEVICES CAPABLE OF USE ON:
  - Armored Vehicles
  - Naval Craft
  - Precision Guided Munitions
  - RPVs
- CIVIL AIRBORNE COMMUNICATIONS EQUIPMENT CAPABLE OF USE ON:
  - Military Transport Aircraft
  - Fighters
  - Fighter-bombers
  - Helicopters
- CIVIL AIRBORNE NAVIGATION AND DIRECTION-FINDING EQUIPMENT CAPABLE OF USE ON:
  - Military Transport Aircraft
  - Fighters
  - Fighter-bombers
  - Helicopters
  - SSMs
- UNDERWATER ACOUSTIC OR ULTRASONIC DEVICES CAPABLE OF USE ON:
  - ASW Patrol Boats

FINDINGS AND CONCLUSIONS

- For most LDCs, motivation for developing a capability to produce arms arose in varying degrees from the concerns for their national security which initiated the arms acquisition process. A factor common to all, however, is their determination to lessen dependence on traditional arms suppliers. Although LDCs wish to be the sole judges of their weapons needs and the timing and circumstances of their employment if threatened with invasion or internal dissension, a connectivity to arms suppliers in the developed world will remain.

- Economic considerations have generally been of secondary importance in the initial decision by LDCs to produce arms indigenously. Over time, however, economic factors began to assume increasing importance. For example, as individual LDCs such as Brazil, Israel and Yugoslavia, developed arms production capabilities, they looked to the arms export market to offset the cost of continuing arms purchases and to reduce overall balance of payments deficits. Others, notably Egypt and India, use arms production to lower unemployment and alleviate the "brain drain."

- Whereas motivations for arms production vary among LDCs there is a common pattern in the stages whereby LDCs achieve an arms production capability (even though the manner and rate of progression through these stages can vary considerably):

    - Arms sales or deliveries by foreign suppliers,

    - Creation of maintenance/overhaul capabilities and facilities to support acquired weapons systems,

    - Assembly and production under license, coproduction, or joint venture agreements with foreign suppliers.

    - Indigenous design and production.

Note: At each of the above stages, LDCs can utilize modular techniques to upgrade the weapons systems in their inventories.

- Despite their efforts to create indigenous arms production capabilities, LDCs will continue to purchase arms abroad in order to meet specific needs, especially at the upper levels of sophistication.

- Since the early 1970's a shift has occurred in LDC patterns of arms acquisition from a limited number of suppliers (predominantly the two superpowers) to many more, primarily in Western Europe. For example, between 1974 and 1977 the British, French and West Germans alone, among the many West European arms suppliers, concluded arms sales in excess of $16 billion, which nearly equalled Soviet sales over the same period. This change has significantly increased LDC options in acquiring arms on terms more favorable to themselves.

- In addition to the expanding role of Western Europe in arms supply, several of the more advanced LDCs specialize in sales to other LDCs thus further broadening the options open to LDCs with regard to the acquisition and employment of weapons systems, primarily at the lower end of the technology spectrum.

- Progress in developing an indigenous arms production capability has been greatest in those LDCs possessing the broadest range of manufacturing technologies, the most sophisticated instrumentalities for controlling and directing investments in defense industries, and the highest levels of competence in their scientific and technical personnel.

- The various forms of licensed production available to LDCs remain the most effective and commonly practiced means of achieving technology transfer and developing a local armaments industry. As competition among suppliers increases, LDCs should be able to conclude more favorable licensing arrangements. Brazil has shown this to be possible.

- Possession of such an infrastructure does not, however, automatically imply the development of an indigenous arms production by any given LDC. Mexico, for example, has an industrial base which compares favorably with the largest LDCs studied yet has so far not undertaken indigenous arms production to the extent practiced by any of the others. If Mexico were for any reason motivated to develop an indigenous arms industry, its progress might be rapid indeed.

- No LDC has developed an indigenous capability to design and produce more advanced weapons systems without recourse to some foreign assistance. This factor does not, by itself, necessarily reflect the technical ability of LDCs over time to reduce the level of such assistance if circumstances so require.* Among the exceptions to this for all LDCs might be the production of advanced jet aircraft engines.

- Virtually all manufacturing technologies are applicable to some phase of arms production, hence can be termed "dual-use technologies." For the production of more advanced weapons systems, however, LDCs would normally prefer to utilize military applications of dual-use technologies. If for any reason military applications are not available, LDCs could then attempt to (a) purchase such products of these dual-use technologies as they can directly adapt to military use, or (b) acquire dual-use technologies through commercial channels with which they themselves can manufacture the required systems.

- Each of the LDCs studied will be able to upgrade obsolescent weapons systems in its possession through purchase of modular military components significantly increasing their threat potential. This study has not addressed the availability of these modular components; however, many of them appear to be accessible to LDCs.

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* Note that interdependence in weapons sytems production is not confined to LDCs but is common in advanced nations. In many instances this is the most cost-efficient way to go.

- A number of LDCs can enhance the performance of systems currently in their possession through the manufacture, either under license, or indigenously, of some of the modular subsystems or components using commercially available dual-use technologies.

- Some LDCs will produce weapons systems, incorporating 1960's vintage technologies, initially under license and gradually increasing the percentage of indigenously produced components, and may then upgrade them by adding modular subsystems or components. The latter may be purchased, manufactured under license or produced indigenously. Commercially available dual-use technology will suffice at this level.

- Indigenous production of weapons systems incorporating 1970's-1980's levels of sophistication would require application of two or more critical dual-use technologies. Because civil utilization of the latter increasingly leads military applications and plays a vital role at many levels of modern industry, they are both available and eagerly sought by LDCs. While, for the present, only Israel among the LDCs studied could absorb them and apply them to advanced weapons construction, it isn't unreasonable to assume that the number of LDCs reaching levels of technical competence which would permit such exploitation of these technologies will gradually increase.

- Future time frames within which LDCs will be capable of absorbing and applying critical dual-use technologies to the design and production of advanced weapons systems may be significantly reduced by comparison with lead time required in the past assuming LDCs are prepared to make the necessary dedication of effort and attendant investment in resources.

- There is little evidence that the LDCs studied have joined in consortium fashion to coproduce advanced weapons systems of their own design.

- So far there is only limited evidence to justify concerns that some LDCs have sought covertly to exploit critical dual-use technologies for the development of advanced, potentially destabilizing weapons systems.* The lack of evidence may derive from the limited scope of the analysis of the problem to date. It is more likely, however, that few LDCs feel it necessary to act covertly in exploiting technologies which are readily available from multiple suppliers.

- In their ability to produce advanced weapons systems, LDCs are clearly well behind the "state of the art" reflected in U.S. designs and will probably remain so. On the other hand, the lower levels of sophistication and complexity represented in the weapons systems LDCs now possessed and are likely to acquire (direct purchase or production) over the next several years could offer advantages to LDC military and naval forces in terms of potential combat and cost effectiveness.

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* There are indications that South Korea, in its efforts to modify and expand the capabilities of the Nike-Hercules surface-to-air missile well beyond its assigned role, has acted with considerable discretion in acquiring commercially from the United States and foreign countries certain components which are essential to the planned modifications. India too, may be using the development of launch vehicles for its civil space program to mask the growth of an IRBM effort.

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